Bulletin of the Psychonomic Society
1976, Vol. 7(1), 25-28

The importance of short-term memory (STM) development for development of acquisition

RICHARD H. BAUER
Department of Psychiatry, School of Medicine, University of California, Los Angeles, California 90024

The sequence length presented to different age groups varied according to the number of items which could be maintained in STM. Unknown to the children, across trials one repeated sequence (RS) reoccurred among nonrepeated sequences (NRS). The results indicated that (a) NRS recall of all ages did not change across trials, (b) RS acquisition was similar for all ages, and (c) NRS and RS recall were positively correlated. Although previous results indicate that acquisition of older children is more rapid than younger children when the same number of items are presented, the present results indicate that acquisition of various ages is similar when STM differences are taken into consideration. These results suggest that STM development can account for development of acquisition.

Acquisition and STM have generally been found to improve with development (Bauer, 1975; Belmont & Butterfield, 1969; Goulet, 1968). It has recently been shown that STM for nonrepeated sequences (NRS) and acquisition of a repeated sequence (RS) improve with development, and furthermore NRS and RS recall are highly correlated (Bauer, 1975). Since multistage learning models suggest that items maintained in STM are eventually transferred to a more permanent store (Atkinson & Shiffrin, 1968; 1971), these results suggest that development of STM is important for development of acquisition. Thus, the more rapid acquisition of older children may be due to maturation of STM processes.

If slower acquisition of younger subjects is due to an inferior STM, equating different ages—so that the number of items presented surpasses the number which can be stored in STM to the same degree—might result in comparable acquisition for different ages. The present experiments were designed to examine this possibility.

The paradigm used in these experiments was similar to that used previously in studying the relationship between development of STM and acquisition (Bauer, 1975). The major difference was that visually presented colored cards were used as stimuli rather than digits. Color sequences were used because digit sequences can readily be grouped into hierarchical structures, and older children are more likely to use these strategies to aid recall (Belmont & Butterfield, 1969). However, rhythmic patterns can be imposed on color sequences which may facilitate recall. Although various organizational strategies can probably never be eliminated, it appears intuitively correct that subjects would be unable to group colors to the same degree as digits and any grouping strategies with colors would probably be less beneficial.

This research was supported by Grant No. MH-24384-01. Data for these experiments was collected while the author was in the University of Houston Department of Psychology. The author gratefully acknowledges the assistance of Barbra Taylor in testing the subjects and the cooperation of the Houston Independent School District.

EXPERIMENT I

Method

Subjects. Four male and four female 7-8-year-old ($\bar{X}$ = 7.9 years) and five male and three female 11-12-year-old ($\bar{X}$ = 11.5 years) students attending the Houston city schools served as subjects.

Apparatus and procedure. Thirty-one quasirandom sequences of the colors: brown, blue, green, red, yellow, purple, orange, pink, black, and white were formed; the only stipulation was that no color occurred more than once in each sequence, and the sequence red, white, and blue was not presented. One of these sequences was randomly selected for the RS and the sequences ordered such that the RS occurred on Trials 2, 5, 9, 26, 31, 35, 38, and 40. Thus, on the average, the same color sequence appeared every fourth trial, and a total of 40 trials was given. The NRS were all different.

Stimuli were presented visually on 25 x 25 cm colored cards through a 10 x 15 cm hole cut in the center of a 60-cm-high x 120-cm-long medium gray screen. The screen was placed on a table so that it separated the child and the experimenter. The colors were presented at approximately one/second, and a 5-sec interval separated the last color in the sequence and the cue for recall. This delay should allow additional time for rehearsal and result in a loss of items held in only a visual or "iconic" memory store (Craik, 1969). Instructions were similar to those used previously (Bauer, 1975), being changed to conform to the nature of visually presented cards. Serial recall was required. The children were not told if they were correct or incorrect nor informed that one sequence was repeated.

The STM of each subject was determined by a pretest given 3-7 days prior to the experiment. Prior to the pretest, each card was presented and the child asked to name the color to insure that he knew the color name. In the pretest, three colors were presented to the younger group and four to the older group on the first trial. On each successive trial, the sequence length was increased by one color per trial until the child failed to recall the sequence perfectly in the order given. This procedure was repeated five times for each subject. The mean number of colors on the last trial in which recall was 100% was then computed for the five trials and a constant of .5 added to this mean. If this number was a fraction, the number was rounded to the next highest or lowest whole number. The number of colors presented in the experiment was this number plus one.

Results and Discussion

The number of colors recalled in the order given was

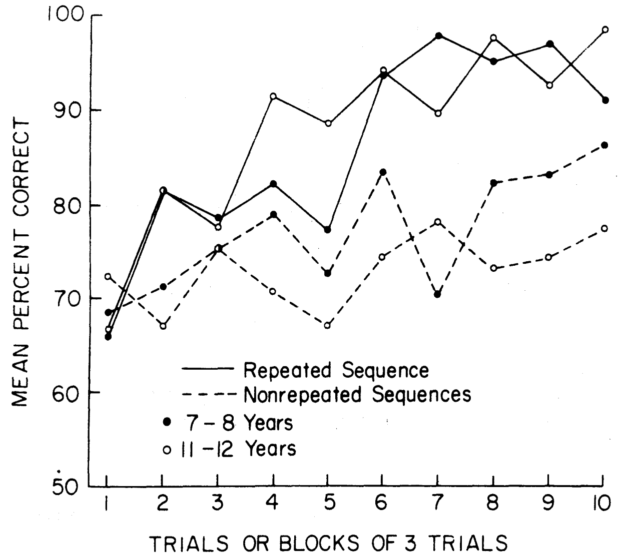

Figure 1. Mean percentage correct recall of a repeated color sequence and nonrepeated color sequences in blocks of three trials for two different age groups.

scored and converted to percentage correct. As would be expected, in the pretest older children recalled significantly longer sequences ($\overline{X}$ = 4.88) than younger children ($\overline{X}$ = 3.75), $t(14) = 2.51$, $p < .05$.

Mean percentage correct recall for each RS trial and NRS recall in blocks of three trials for both groups is presented in Figure 1. A 2(age) by 10(trials) complete factorial analysis of variance of the percentage correct RS recall, with the last factor as a repeated measures variable, showed that there was significant improvement across trials, $F(9,125) = 5.72$, $p < .001$. The main effect for age and the Age by Trials interaction were not significant. Since acquisition of younger children is slower than that of older children when the same amount of information is presented but no different when the number of colors which can be stored in STM is taken into consideration, slower acquisition of younger children may be due to an inferior STM.

A 2(age) by 10(blocks of three trials) mixed analysis of variance of the percentage NRS recall revealed no significant main effects or interaction. These findings provide evidence that the two groups were equated for STM performance. In addition, they suggest that STM changes little with practice.

A t test for correlated measures between the total percentage correct RS and NRS recall for the two age groups combined showed that RS recall was superior, $t(15) = 4.11$, $p < .001$. Superior RS recall is probably due to RS improvement across trials.

The correlation between RS and NRS recall for both ages combined was significant, $r(14) = .65$, $p < .005$, suggesting that individual differences in STM are important for acquisition.

EXPERIMENT II

Experiment I indicated that acquisition of different ages is similar when the number of items presented exceeds color span to approximately the same degree. The present experiment was designed, in part, to determine if a similar effect occurs with more divergent ages.

Also, in Experiment II, colors were presented in either the visual or auditory mode to examine the effects of modality on RS and NRS recall. Using juvenile subjects, Horowitz (1969) found a significant modality effect but no significant Age by Modality interaction. However, Dornbush and Basow (1970) reported an interaction between presentation rate, presentation modality, and development. For first graders, auditory presentation was superior to visual presentation at .5, 1, and 2 digits/second. From the third through the ninth grades, presentation rate had little effect on recall of digits presented auditorily; but throughout this developmental period, there was a positive relationship between presentation rate of digits presented visually. It has been suggested that for rehearsal and/or for verbal recall, incoming visual items must first be transferred into an auditory code; and this processing requires more time than for items already in the auditory mode (Glanzer & Clark, 1963). In light of this suggestion, it appears that first graders could not transfer visually presented digits into an aural code at even the slowest presentation rates but that during development transfer from a visual to an aural code becomes progressively faster until adult levels are attained. Therefore, NRS recall and possibly RS acquisition of younger children may be superior with auditory as compared to visual presentation.

Method

Subjects. Eight male and 12 female 4-5-year-old ($\overline{X}$ = 4.6) kindergarten students and 12 male and 8 female 9-10-year-old ($\overline{X}$ = 10.1) elementary students in Houston, Texas served as subjects.

Apparatus and procedure. Preliminary research with 4-5-year-olds indicated that without reinforcement they would participate for relatively few trials. Therefore, M&M candy was given approximately every five trials, and the RS was presented more often, i.e., on Trials 2, 4, 7, 11, 16, 21, 25, and 28. Thus, a total of 28 trials was given. The colors were presented either visually or auditorily. For visual presentation, the apparatus and procedure of Experiment I were used. During auditory presentation, the experimenter said the color names at approximately one/second in a monotone voice.

As in Experiment I, subjects were given the pretest. The pretest results showed that older children recalled significantly longer color sequences ($\overline{X}$ = 4.81) than did 4-5-year-olds ($\overline{X}$ = 3.16), $t(38) = 3.86$, $p < .001$, but the modality effect was not significant. Since younger children recalled fewer items, increasing the number of items presented in the experiment by one color more than younger children could correctly recall in the pretest would be a greater percentage increase than for 10-year-olds. Therefore, on the basis of the pretest results, sequences of four colors each were presented to 4-5-year-olds and six colors to 9-10-year-olds.

Results and Discussion

Figure 2 depicts the mean percentage RS recall for each group. As can be seen, on the first trial, recall of the four groups was similar, which indicates that the children were equated for the number of items stored in STM. A 2(age) by 2(modality) by 8(trials) complete factorial analysis of variance, with the last factor as a repeated measures variable, indicated that the main effect for trials was the only significant term, F(7,262) = 4.27, p < .001. These results provide further support for the suggestion that slower acquisition of younger children is due to an inferior STM.

For 4-5-year-olds, NRS recall was superior when the colors were presented in the auditory ($\bar{X}$ = 69.37%) as compared to the visual mode ($\bar{X}$ = 60.34%); but for 9-10-year-olds, modality had little effect (auditory, $\bar{X}$ = 69.41%; visual, $\bar{X}$ = 72.17%). However, a complete factorial analysis of variance of the percentage correct NRS recall in blocks of three trials showed that neither the main effect for modality, F(1,36) = .78, nor the Age by Modality interaction, F(1,36) = 3.25, p < .10, were significant. All other main effects and interaction terms were small and nonsignficant.

Failure to find a significant Age by Modality interaction may be due to the type of material presented. Dornbush and Basow (1970) presented digits in either the auditory or visual mode at rates from .5-2.0 digits/second and found that for first grades, auditory presentation was superior at all rates. Since younger children may be more familiar with color names than digits, less time would be required to translate visually presented colors into an aural code than to translate visually presented digits. Thus, for more familiar items, a relatively faster presentation rate may be required for the occurrence of a modality effect than for less familiar items. The fact that longer color sequences were presented to older children probably cannot account for the failure to find a modality effect, because Dornbush and Basow (1970) also varied the number of digits presented according to the digit span of each age.

For correlated measures between the total percentage RS and NRS recall, t tests showed that RS recall of 9-10 [t(19) = 2.26, p < .05], and 4-5-year-olds [t(19) = 4.98, p < .001] was superior. Improved RS recall probably accounts for this difference.

Correlations between the total percentage RS and NRS recall for the older, [F(18) = .40, p < .05] and younger [r(18) = .47, p < .05] groups were significant. These correlations provide additional support for the suggestion that STM is important for acquisition.

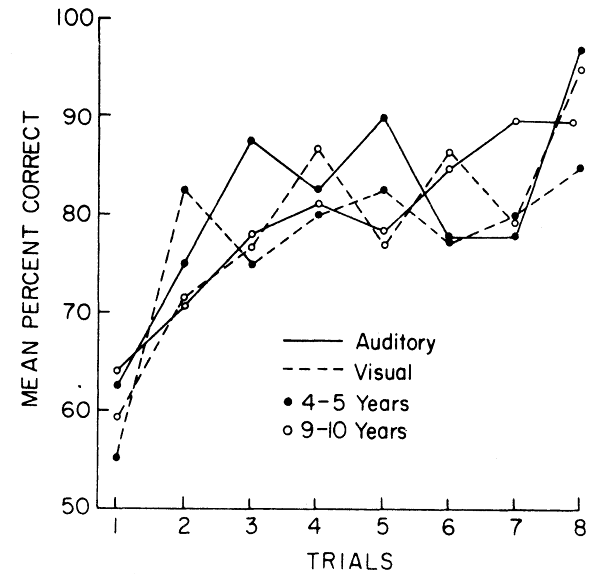

Figure 2. Mean percentage correct recall of a repeated color sequence presented in the visual or auditory mode for 4-5- and 9-10-year-old children.

GENERAL DISCUSSION

The finding that recall of older children was superior to that of younger children in the pretest indicates that the number of items maintained in STM increases with age. However, NRS recall changed very little across trials, suggesting that the number of items maintained in STM remains relatively constant with practice.

Although acquisition of older children is superior to younger children when the same number of items are presented (Bauer, 1975; Goulet, 1968), the present results indicate that if the number of items presented varies according to each subject's NRS recall, RS acquisition is very similar. Therefore, the number of items stored in STM appears to account for the differential acquisition of children differing in age. There is also reason to believe that, with adults, individual differences in STM can account for individual differences in the rate of acquisition.

Although acquisition improves with development, forgetting rate is invariant with age (e.g., Belmont & Butterfield, 1969). Therefore, differential forgetting in the delay does not appear to account for the recall differences found in the present study. Belmont (1972) has shown that forgetting rate of different age and IQ children is similar when number of items presented varies according to STM of each child. The present results suggest that acquisition, like forgetting, is no different if the amount of information which can be maintained in STM is taken into consideration.

REFERENCES

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2). New York: Academic Press, 1968.

Atkinson, R. C., & Shiffrin, R. M. The control of short-term memory. *Scientific American*, 1971, **224**, 82-90.

Bauer, R. H. Development of short-term memory (STM) and acquisition. *Bulletin of the Psychonomic Society*, in press.

Belmont, J. M. Relations of age and intelligence to short-term color memory. *Child Development*, 1972, **43**, 19-29.

Belmont, J. M., & Butterfield, E. C. The relations of short-term memory to development and intelligence. In L. P. Lipsitt & H. W. Reese (Eds.), *Advances in child development and behavior*. New York: Academic Press, 1969.

Craik, F. I. M. Modality effects in short-term storage. *Journal of Verbal Learning and Verbal Behavior*, 1969, **8**, 658-664.

Dornbush, R. L., & Basow, S. The relationship between auditory and visual short-term memory and reading achievement. *Child Development*, 1970, **41**, 1033-1044.

Glanzer, M., & Clark, W. Accuracy of perceptual recall: An analysis of organization. *Journal of Verbal Learning and Verbal Behavior*, 1963, **1**, 289-299.

Goulet, L. R. Verbal learning and memory research with retardates: An attempt to assess developmental trends. In N. R. Ellis (Ed.), *International Review of Research in Mental Retardation*, 1968, **3**, 97-134.

Horowitz, A. B. Effects of stimulus presentation modes on children's recall and clustering. *Psychonomic Science*, 1969, *14*, 297-298.

(Received for publication September 29, 1975.)